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Coyote hair as an area repellent for white-tailed deer

(*Keywords: Canis latran*, coyote, deterrent, hair, *Odocoileus virginianus*, white-tailed deer)

T. W. SEAMANS*, B. F. BLACKWELL and J. D. CEPEK

United States Department of Agriculture, National Wildlife Research Center, 6100 Columbus Avenue, Sandusky, OH 44870, USA

Abstract. Increasing white-tailed deer (*Odocoileus virginianus*) populations create numerous conflicts with agricultural production and transport safety. Lethal control is not always an option and area repellents, such as predator waste products, have generally shown limited effectiveness. We tested coyote (*Canis latrans*) hair as a repellent at feeding stations during the winters of 2000 and 2001 and along established deer trails during the summer of 2000 in northern Ohio. Feeding station experiments were conducted in which five treatment sites received one or three bags containing 17 g of coyote hair placed adjacent to or in front of a trough of whole kernel corn and five control sites received empty bag(s). In all feeding trials, corn consumption decreased at treated sites from 59 to 91%. Intrusions by deer at treated sites decreased by 48–96% in three tests, but did not vary in the first 3-week test when coyote hair was adjacent to the corn. Corn consumption and deer intrusions at control sites generally remained constant or showed an increase over the test period. In the deer trail test, use of trails did not differ between the pre-treatment and treatment periods for the control or treated trails. Coyote hair therefore served as an effective repellent to keep deer from a desired food source and should have use in protecting limited, discrete sites. However, coyote hair did not deter deer from moving along established trails.

1. Introduction

White-tailed deer populations (*Odocoileus virginianus*) in the USA increased from about 350000 in 1900 to >26 million individuals in the 1990s (Jacobson and Kroll 1994). White-tailed deer cause extensive damage to orchards, nurseries, and ornamental trees and shrubs (Scott and Townsend 1985, Purdy *et al.* 1987, Sayre and Decker 1990). Farmers as well as agricultural and wildlife agencies have ranked deer as causing more crop damage overall than any other group of wildlife (Conover and Decker 1991, Wywialowski and Beach 1992). High-density deer populations may also adversely affect native plant communities, including reforestation efforts (Craven and Hygnstrom 1994, Waller and Alverson 1997).

Deer residing near airports pose a direct threat to operational and public safety. They are often attracted to airports to forage and have become a concern as the number of reported deer-aircraft collisions increase (Bashore and Bellis 1982, Wright 1996, Wright *et al.* 1998, Dolbeer *et al.* 2000). From 1990 to 1999, there were 420 reported civil aircraft collisions with deer in the USA (Cleary *et al.* 2000). Deer-vehicle collisions are also increasing and represent additional threats to the travelling public (Conover *et al.* 1995, Romin and Bissonette 1996).

Direct removal of deer can reduce agricultural damage and the potential for deer-aircraft collisions; however, such action is often controversial. Various non-lethal mechanical (e.g., fences, cattle guards, propane exploders) or biological (dogs) techniques are available to reduce depredations and collisions (Beringer *et al.* 1994, Craven and Hygnstrom 1994, Belant *et al.* 1996, 1998a). However, these techniques are expensive and impractical in many nuisance situations. Further, ultrasonic and sonic devices have been ineffective as repellents for deer (Romin and Dalton 1992, Belant *et al.* 1998b).

Application of certain repellents directly to food as taste aversive treatments can suppress feeding by deer (Conover 1984, 1987, Conover and Kania 1987, Sullivan *et al.* 1988, Swihart *et al.* 1991, Wagner and Nolte 2001). However, odour-based repellents generally have been ineffective in protecting a food source (Conover 1984, Belant *et al.* 1998c, Brown *et al.* 2000). Conover and Kania (1987) suggested that effectiveness of a repellent partially depends on the palatability of the food source. For example, when bags of human hair were used to protect yews (*Taxus* spp.) from deer, the hair was found to be ineffective (Conover 1984). However, when bags of human hair were put on less palatable apple trees, a measure of protection was achieved (Conover and Kania 1987).

Sullivan *et al.* (1985) concluded that mule deer (*O. hemionus*) were repelled by odours that indicated 'predator'. Swihart *et al.* (1991) contend that 'threat signals' were from odours associated with predators that preyed upon deer and not with novel or nonpredator odours that did not represent a threat to deer. Wagner and Nolte (2001) tested 20 deer repellents and found that those eliciting fear were the most effective. Belant *et al.* (1998c) suggested that the marginal effectiveness of predator urine when used as an area repellent in excluding deer from a food source was relative to the threat perceived by the deer.

Predator hair has not been evaluated as an area repellent for deer. Based on the partial repellency of human hair on apple trees (Conover and Kania 1987), the predation of coyotes (*Canis latrans*) on deer, and the theory of 'relative threat signals' (Sullivan *et al.* 1985, Swihart *et al.* 1991), we hypothesized that coyote hair would repel deer. The National Wildlife Research Center Animal Care and Use Committee approved procedures involving deer before the start of the study (QA-491).

*To whom correspondence should be addressed. e-mail: THOMAS.W.SEAMANS@USDA.GOV

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2. Materials and methods

In 2000, we ran tests from January through March (Experiment 1) and August through September (Experiment 2); in 2001, tests ran from January through March (Experiment 3). All experiments were conducted at the National Aeronautic and Space Administration's Plum Brook Station (PBS), Erie County, Ohio. A 2.4-m high chain-link fence with barbed-wire outriggers encloses the 2,200-ha facility. Habitat within PBS differed from the surrounding agricultural and urban area and consisted of canopy-dogwood (*Cornus* spp.) (39%), grasslands (31%), open woodlands (15%), and mixed hardwood forests (11%) (Rose and Harder 1985). The estimated minimum white-tailed deer population on PBS was 412 (19/km^2) in 2000 and 2001 (A. E. Barras, US Department of Agriculture, unpublished data). All coyote hair used in this study was shaved off euthanized captive coyotes that had been part of separate National Wildlife Research Center research projects in Logan, Utah. The coyotes had not been part of chemical tests that would have resulted in foreign chemical deposition in the hair (Mason, J. R., 2000, Personal communication).

2.1. Experiment 1

During January 2000 we established ten 5 × 5-m deer feeding sites, each at least 1 km from the nearest site. A plastic snow fence (1.5-m high) was erected on three sides of each site; with a 1.2-m long feed trough supplied with whole-kernel corn located inside the fenced area and centred about 1 m from the rear fence. To monitor whole-kernel corn consumption, each feed trough was fitted with two metal indicator plates that had been inscribed at calibrated 4.5-kg intervals for whole-kernel corn and positioned at each end of the trough (Belant *et al.* 1997). We estimated corn consumption to the nearest 2.3 kg by interpolating the distance between the 4.5-kg intervals. Corn was added to feed troughs as necessary to maintain a constant food supply (about 25 kg). An active infrared monitoring device (TrailMaster^R, Goodson and Associates, Incorporated, Lenexa, Kansas) that requires an infrared beam to be broken before an animal is counted was installed 60 cm above ground at each opening to continually monitor the number of deer intrusions and avoid recording non-target species (e.g. raccoons (*Procyon lotor*) and fox squirrels (*Sciurus niger*).

2.1.1. Test 1. This test consisted of three 7-day periods; pre-treatment, treatment and post-treatment (13 January–2 February 2000) during which corn consumption and deer activity were monitored at each site. The pre-treatment week was initiated after there were seven consecutive days of daily corn consumption at each of the 10 sites. We randomly selected five sites for application of the hair treatment. At each treated site, a nylon mesh bag, 50-cm long, containing 17 g of coyote hair (approximately 200 cm^2) was positioned on a metal pole adjacent to and centred on the back edge of the feed trough so that the bottom of the bag brushed the edge of the trough. The remaining five sites (i.e. control sites) were treated similarly except the bags were empty. After the treatment week, all bags were removed. The post-treatment week allowed us to evaluate extended treatment effects after removal of the coyote hair.

Because white-tailed deer home ranges can exceed 1 km (Marchinton and Hirth 1984), we did not consider treated and control sites as independent (i.e., the same deer could possibly feed at multiple sites within and between treatments). We also assumed that our sample size of feeding stations ($n = 10$) and the estimated number of deer present would produce substantial intrusions and corn consumption and approximate normality with regard to site-specific corn consumption per unit time. Due to the lack of independence between sites, assumptions for both parametric and non-parametric tests would be violated. We therefore compared use of one resource type (corn) between periods within a treatment (i.e. hair-treated sites or controls) by use of 95% confidence limits (Haney and Solow 1992, Cherry 1996, Johnson 1999, Brown *et al.* 2000). We calculated binomial confidence limits about the proportion of total corn consumption and separately around intrusions that occurred during the pre-treatment period (p_{pt}) as

$$p_{pt} \pm z_{(1-\alpha/2)}[p_{pt}(1-p_{pt})/N]^{1/2},$$

where N is the total corn consumption or intrusions within a treatment and over the pre-treatment, treatment, and post-treatment periods. The confidence interval thus served as a basis for evaluating increase or decrease in corn consumption or intrusions in subsequent periods. If confidence coefficients did not include expected values, then observed and expected proportions differed significantly ($\alpha = 0.05$ $Z_{(1-\alpha/2)} = 1.96$). However, though we calculated separate intervals for pre-treatment corn consumption and intrusions at treatment and control sites (i.e. a within-treatment comparison), corn was present concurrently at all sites and, thus effects of coyote hair on corn consumption and intrusions at treated versus control sites can be inferred.

2.1.2. Test 2. This test differed from Test 1 by having only two periods, a 7-day pre-treatment and a 35-day treatment period (5 February–17 March 2000). The treatment period extended until alternate foods (spring vegetation growth) were readily available within the study area. Treatment and control sites were selected by alternating the sites from Test 1 (i.e. control sites in Test 1 became treatment sites in Test 2). The same bags of hair used in Test 1 were used in Test 2. We again compared corn consumption within treatments and between periods using 95% confidence intervals.

2.2. Experiment 2

Ten active deer trails were located about 1 km apart. Active infrared trail monitoring devices were set 60 cm above the ground to avoid counting non-target animals using the trails. Trails were monitored until all trails were used consistently for 3 weeks (18 August–8 September 2000). Five trails were randomly selected to receive a mesh bag containing 16 g of coyote hair while the remaining five trails received an empty mesh bag. At each site a bag was hung 2 m above the ground from a tree branch, over the trail and above the infrared beam of the trail-monitoring device. All trails were then monitored for 3 weeks (8–29 September 2000). Trail monitors were occasionally knocked out of alignment or had the infrared beam blocked by vegetation, resulting in the loss of data for 1 to 2 days.

Therefore, we report results as mean crossings per day. We calculated 95% confidence limits about the mean daily trail use within treatment and between periods.

2.3. *Experiment 3*

During January 2001 we re-established the feeding stations used in Experiment 1. The only changes from Experiment 1 were that a metal fence post was placed midway across the front of the enclosure opening, 30 cm in front of the infrared monitoring beam and three bags were placed at the front of the enclosure. One bag each was placed 1 m above the ground on the two front corner posts and the centre post. The five control sites received empty bags while the five treatment sites received bags each containing 17 g of coyote hair.

2.3.1. Test 1. This test was conducted in the same manner as Test 1 of Experiment 1. The three 7-day periods occurred from 10 - 30 January 2001.

2.3.2. Test 2. As in Experiment 1, this test differed from Test 1 of Experiment 3 by having only two periods, a 7-day pre-treatment and a 35-day treatment period (6 February–19 March 2001). Treatment and control sites were selected by alternating the sites from Experiment 3, Test 1 (i.e. control sites in Test 1 became treatment sites in Test 2). The same bags of hair used in Experiment 3, Test 1 were used in Experiment 3, Test 2. We again compared corn consumption and intrusions within treatments and between periods using 95% confidence intervals.

3 Results

3.1. *Experiment 1*

3.1.1. Test 1. Total corn consumption across control sites increased by 37% from the pre-treatment to the treatment week and changed little through the post-treatment week. In contrast, total corn consumption across treatment sites decreased by 59% over the treatment week relative to the pre-treatment week total and then increased during the post-treatment week, surpassing the pre-treatment week by 9% (figure 1).

Total deer intrusions across control sites increased by 29% from the pre-treatment to the treatment week, and then decreased by 10% during the post-treatment week relative to the treatment week. Total deer intrusions at treatment sites were similar in pre-treatment and treatment weeks and then increased by 17% during the post-treatment week (figure 1).

3.1.2. Test 2. Corn consumption across control sites showed a mean increase (29%) from the pre-treatment week through the five treatment weeks with the last two treatment weeks having greater consumption (44% and 61%, respectively) than the pre-treatment week. In contrast, weekly corn consumption across treatment sites was less ($\bar{x}=75\%$) over the entire 5-week treatment period relative to the pre-treatment week (figure 2).

Intrusions across control sites showed a general increase ($\bar{x}=19\%$) from pre-treatment through the five treatment weeks with weeks two, four, and five having more intrusions ($x=32\%$) relative to the pre-treatment week. Intrusions across treated sites were less ($\bar{x}=48\%$) than the pre-treatment week for the entire 5-week treatment period (figure 2).

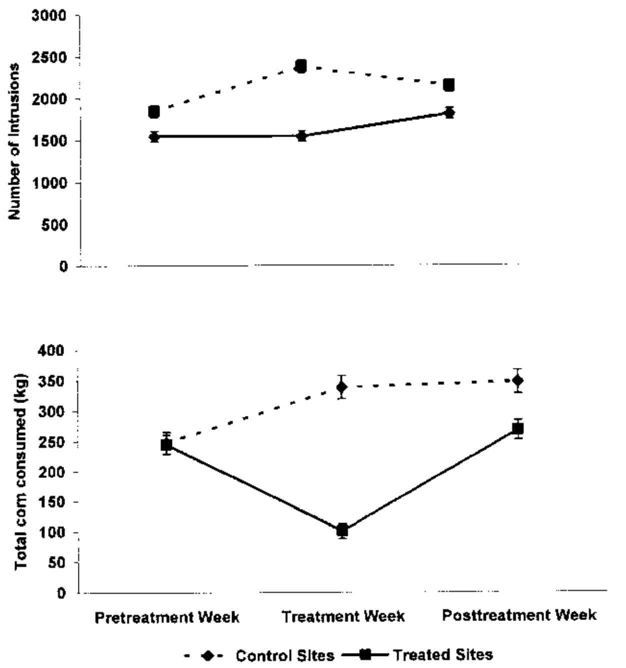

Figure 1. Total number of intrusions/week and corn consumed (kg)/week (95% confidence intervals indicated by error bars) by white-tailed deer at five sites with a bag of coyote hair (17 g) hung adjacent to the corn and at five sites with an empty bag during 1-week pre-treatment, treatment and post-treatment periods from 13 January –2 February 2000, Erie County, Ohio.

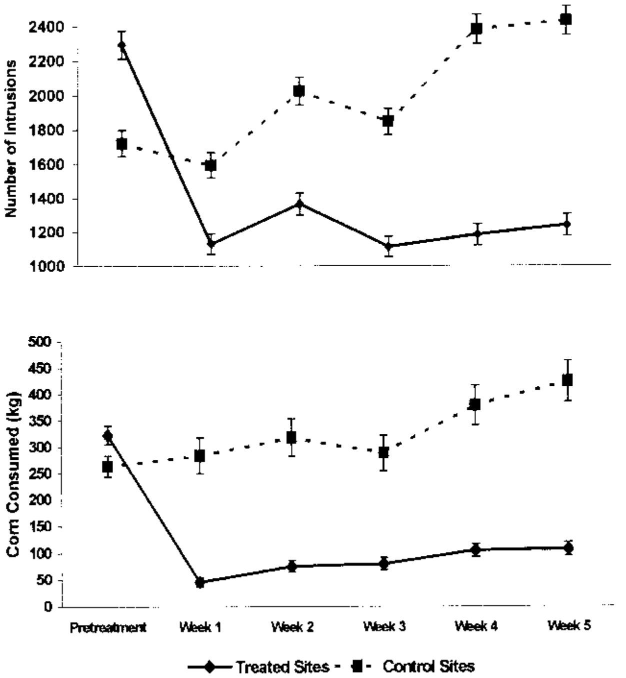

Figure 2. The total number of intrusions/week and corn consumed (kg)/week (95% confidence intervals indicated by error bars) by white-tailed deer at five sites with a bag of coyote hair (17 g) hung adjacent to the corn and five sites with an empty bag during a 1-week pre-treatment and 5-week treatment period from 5 February – 17 March 2000, Erie County, Ohio.

3.2. Experiment 2

Trail use did not differ between the pre-treatment and treatment periods for the control trails or for the treated trails (figure 3).

3.3. Experiment 3

3.3.1. Test 1. Total corn consumption across control sites remained constant through the pre-treatment, treatment, and post-treatment weeks. In contrast, total corn consumption across treatment sites decreased by 91% over the treatment week relative to the pre-treatment week total, then increased during the post-treatment week to within 50% of the pre-treatment total (figure 4).

Intrusions across control sites decreased by 11% from the pre-treatment to the treatment week and then increased during the post-treatment week relative to the pre-treatment (26%) and treatment (41%) weeks. Intrusions across treatment sites decreased by 96% over the treatment week relative to the pre-treatment week and then increased during the post-treatment week to within 37% of the pre-treatment total (figure 4).

3.3.2. Test 2. Corn consumption across control sites showed a general increase from the pre-treatment week through the five treatment weeks. All treated weeks had greater ($\bar{x}=77\%$) consumption than the pre-treatment week with weeks three and five having greater consumption than treatment weeks one and two. In contrast, weekly corn consumption across treatment sites was less ($\bar{x}=61\%$) over the entire 5-week treatment period relative to the pre-treatment week (figure 5).

Intrusions across control sites showed a general increase ($\bar{x}=85\%$) from pre-treatment through the five treatment weeks. In contrast, intrusions across treated sites were less ($\bar{x}=79\%$) than the pre-treatment week for the entire 5-week treatment period (figure 5).

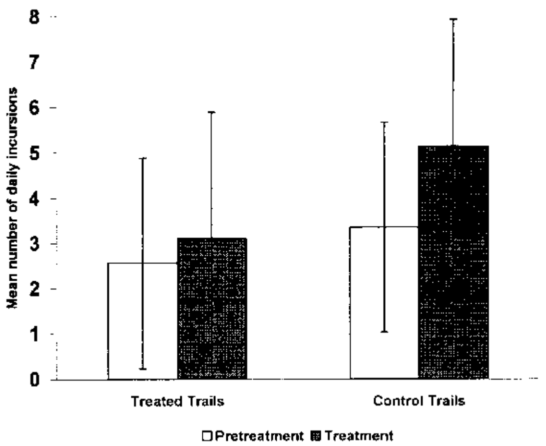

Figure 3. The mean daily number (95% confidence intervals indicated by error bars) of white-tailed deer using five deer trails that each had a bag of coyote hair (16 g) hung above the trail (treated) and five trails with an empty bag hung above the trail (control) during a 3-week pre-treatment and 3-week treatment period from 18 August - 29 September 2000, Erie County, Ohio.

4. Discussion

Ideally, it would have been best to test coyote hair on ten unique and independent deer populations. Such a situation would allow for a parametric approach (e.g., paired different *t*-test) to discern effects due to the treatments. However, the prospect of locating 10 unique populations that have homo-

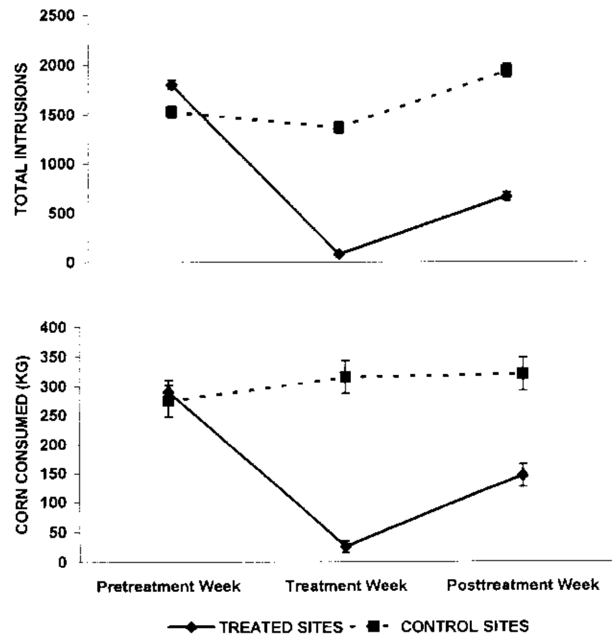

Figure 4. Total number of intrusions/week and corn consumed (kg)/week (95% confidence intervals indicated by error bars) by white-tailed deer at five sites with three bags of coyote hair (17 g) at the front of the enclosure and at five sites with empty bags during 1-week pre-treatment, treatment and post-treatment periods from 16 - 30 January 2001, Erie County, Ohio.

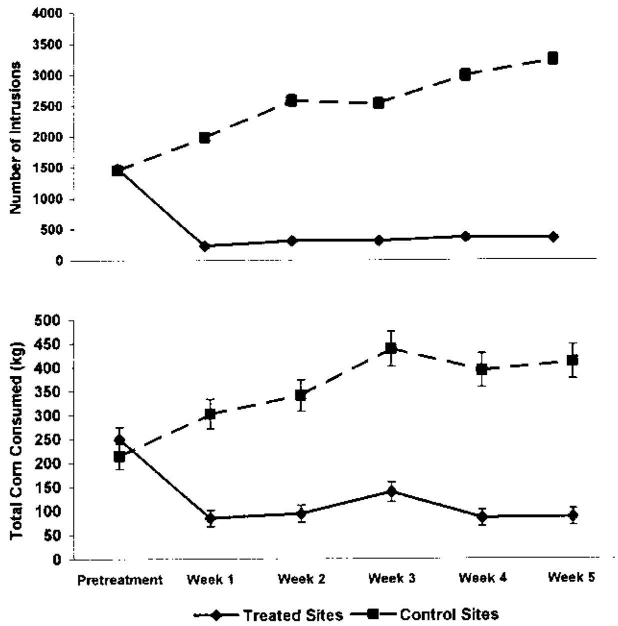

Figure 5. Total number of intrusions/week and corn consumed (kg)/week (95% confidence intervals indicated by error bars) by white-tailed deer at five sites with three bags of coyote hair (17 g) at the front of the enclosure and at five sites with empty bags during 1-week pre-treatment and 5-week treatment periods from 6 February- 19 March 2001, Erie County, Ohio.

geneous weather and habitat conditions is nearly logistically impossible. In the current test, where we could not be assured of independent populations (though our experimental area comprised 2,200 ha) we contend that the use of confidence intervals provided a viable description of events. Specifically, this analysis allows for an estimate of the size of the effect and a measure of uncertainty (Johnson 1999).

Coyote hair placed adjacent to, or within 5 m of, whole kernel corn during the winter in northern Ohio was repellent to white-tailed deer. Even after 5 weeks of treatment a measure of protection was achieved. For example, in Test 2 of Experiment 3, deer intrusions at treated sites remained below 21% of pre-treatment levels for the entire 5-week treatment period. In contrast, control site intrusions increased 2.2 fold from pre-treatment to week five of the test. It is notable that these reductions occurred in an area with a high deer population (>19 deer/km^2) exposed to a highly desirable food during an energetically stressful time of the year. Although we cannot assume control and treatment sites are independent, it is notable that for each test there was a striking difference in feeding and intrusions between treated and control sites after placement of coyote hair. These differences held even when treated and control sites were switched.

However, deer use of established deer trails in summer was not altered by the presence of bags of coyote hair hung above the trails. Further, there was no evidence that deer deviated from established trails at any point. Because a bag of hair or an empty control bag was clearly visible over trails, visual deterrence by coyote hair at feeding troughs seems unlikely. In previous experiments, visual repellents (mylar ribbon) have not deterred deer from corn (Dolbeer *et al.* 1986, Belant *et al.* 1997). Also, the lack of comparable results in Conover's (1984) work with human hair as a deer repellent is indicative that our findings are not the result of a visual deterrent.

Coyotes may serve as significant predators on local deer populations (Hesselton and Hesselton 1982, Mech 1984). Eastern coyotes are present on the study area and although their predation rate on the PBS deer population is unknown, we have observed coyotes feeding on and chasing deer within the study area. Cepek (2000) reported that 20% of coyote faeces in the Cuyahoga Valley National Recreation Area, Brecksville, Ohio (about 100 km from PBS) contained deer remains, much of which was likely eaten as carrion. The coyote hair used in this study was shaved from dead, western coyotes. We do not know if hair of western and eastern coyote races differ in texture or odour. Nevertheless, deer avoided troughs of corn treated with bags of western coyote hair. The long-term avoidance noted in both 5-week tests supports the Sullivan *et al.* (1985) and Swihart *et al.* (1991) theories of relative threat signals whereby deer are reacting to a perceived threat from a known predator and not to a novel odour. However, the lack of deterrence at trail sites also indicates that deer were willing to pass a potential threat signal that did not 'defend' a food source.

Also, though we did not specifically measure raccoon activity, we noticed raccoon tracks and faeces in corn troughs and on the posts holding the bags at both treated and control sites throughout both 5-week experiments. Therefore it would appear that raccoons were not repelled by coyote hair.

Unlike the minimal repellency noted when coyote urine was used in similar tests (Belant *et al.* 1998c), the long-term repellency from coyote hair indicates that deer are detecting a stable odour that consistently renews a perceived threat to deer approaching the site. Hair is rich in cystine, a sulphur-containing amino acid. Sulphur-containing chemicals and volatile fatty acids, by products of meat digestion, are credited with causing predator urine and faeces to be repellent to herbivores (Epple *et al.* 1993, Nolte *et al.* 1994, Mason *et al.* 1999). Should a distinct compound be isolated in coyote and other predator hair that is consistent with an expected repellent behaviour, then development of a synthetic chemical that could be used in concentrated form in lieu of actual hair will be pursued. The development of an inexpensive synthetic repellent would allow homeowners or others an economically feasible and practical deer deterrent. In the interim, coyote hair provides a measure of repellency for those who need to reduce white-tailed deer activity or feeding in a specified area.

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